37

ON THE THERMAL NEUTRON CAPTURE CROSS-SECTIONS

H. S. HANS AND M. L. SEHGAL

DEPARTMENT OF PHYSICS, MUSLIM UNIVERSITY, ALIGARH

(*Received for publication, March 17, 1958.*)

ABSTRACT. Experimental and theoretical values of thermal neutron capture cross-sections have been compared for a number of cases. An attempt is made to explain the discrepancy in many cases. It is proposed that in the case of Ag^{107}, Ni^{62}, In^{113}, Hg^{199}, Mo^{97}, and Hf^{170}, there exist negative energy levels close to zero energy. Radiation width in the case of Co^{59} is considered to be 0.6 ev, instead of 0.2ev as given by Segrè.

1. INTRODUCTION

Thermal neutron absorption as well as activation cross-sections have been more or less exhaustively measured. They have been tabulated in the AECU-2040 (1955) report. It is possible to evaluate exactly the thermal neutron capture cross-sections theoretically, if the various parameters of the resonances near the zero energy are exactly known. Breit-Wigner single level dispersion formula should be valid in most of these cases, where resonances are separated enough to neglect any interference effects It will be interesting to compare the experimental and theoretical values of these cross-sections. Any discrepancy between these values should reveal that either the information about the parameters of the nearest known resonances is inadequate or there are still other resonances on the positive or negative side of the zero energy.

2. DISCUSSION

In Tables I and II are presented the theoretical and experimental values of thermal neutron capture cross-sections at 0.025ev. The experimental values are invariably taken from AECU–2040 (1955) report . The theoretical values are calculated from Breit-Wigner single level formula (Blatt and Weisskopf, 1952).

$$\sigma_0(n, \gamma) = \frac{g\lambda_0^2}{4\pi} \frac{\Gamma_n\Gamma_r}{(E_0-E_r)^2+(\frac{1}{2}\Gamma)^2} \left(\frac{E_0}{E_\gamma}\right)^{1/2}$$

where $\sigma_0(n, r)$ is the cross-section at 0.025ev; g is the statistical weight factor; λ_0 is the neutron wave length at 0.025 ev Γ_n and Γ_γ are the neutron and the radition widths of the reasonance under consideration; $E_0 = 0.025$ev; E_r is the resonance energy in electron volts and Γ is the total width given by

$\Gamma = \Gamma_n + \Gamma_\gamma + \ldots$. Interference effects due to the nearness of two levels of the same J and parity are, of course, neglected. The sources from which the values of various parameters are taken are given in the tables.

Table I represents those cases where the ratio R is 1 within the uncertainties involved either in the resonance parameters used in the Breit-Wigner formula or in the experimental values of σ_0. In cases where I the total angular momentum of the target nucleus is very much greater than one, the value of J is taken to be $I + \frac{1}{2}$ which anyhow does not differ very much from the value $I - \frac{1}{2}$. The values of J of the compound nucleus of other cases given in Table I are normally taken from the existing literature.

In Table II are listed those cases for which the ratio R is generally quite different from 1. In the first three cases i.e. Hf^{177} I^{127}, and Tb^{159}, it is found that the contribution to σ_0 from resonances other than the nearest one is comparable to the first one. The case of I^{127} is of particular interest where the contribution from the first level is hardly ten per cent of the total value. While in the case of Hf^{177} the experimental σ_0 is fully explained by taking into account the other resonances, the discrepancies in Tb^{159} and I^{127} are still unexplained. It appears possible that negative energy levels may be contributing appreciably in these cases. Other cases in this table cannot be explained by the known positive energy resonances even taking into account the experimental uncertainties involved. Careful consideration of the resonances of Ag^{107}, Ni^{62}, In^{113}, Hg^{199} and

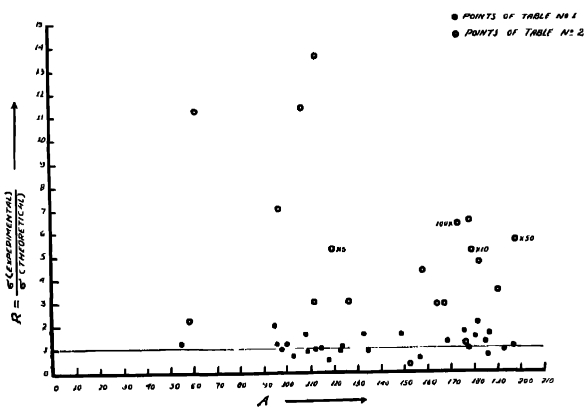

Fig. 1

Mo^{97} where the value of R is very high, suggests very strongly the existence of negative energy resonances. In the case of Ag^{107} and Hg^{199} the negative energy resonances are also pointed out by Wood (1956) and Segre (1953). In calcula-

TABLE I

S.N.	Isotope	J value of compound nucleus	σ_0 in barn Calculated	Experimental	Ratio R	Reference
1	Mn^{55}	2	11.1	13.2	1.2	Bollinger *et al.* (1955)
2	Mo^{95}	3	6.5	13.4	2.0	AECU–2040 (1955)
3	Mo^{96}	$\frac{1}{2}$	1.0	1.2	1.2	–do–
4	Mo^{98}	$\frac{1}{2}$	0.16	0.4	1.0	–do–
5	Mo^{100}	$\frac{1}{2}$	0.41	0.5	1.2	–do–
6	Rh^{103}	0	71.8	150	2.0	–do–
		1	215.5	150	0.7	
7	Pd^{108}	$\frac{1}{2}$	7.4	12	1.6	Segre (1953)
8	Ag^{109}	1	92.5	84	0.9	Wood (1956)
9	Cd^{113}	1	19974	20800	1.0	Sailor (1956)
10	In^{115}	4	181	197	1.0	AECU–2040 (1955)
11	Sn^{118}	$\frac{1}{2}$	0.02	0.01	0.5	–do–
12	Te^{123}	1	413	390	0.9	–do–
13	Sn^{124}	$\frac{1}{2}$	0.17	0.20	1.1	–do–
14	Cs^{133}	4	17.5	29.0	1.6	–do–
15	Xe^{135}	2	2.94	2.7	0.9	AECU–2040 (1955) Deutsch (1956)
16	Sm^{149}	4	31420	50000	1.6	AECU–2040 (1955)
17	Gd^{157}	3	256964	160000	0.6	–do
18	Tm^{169}	1	86	118	1.3	–do–
19	Lu^{176}	15/2	2361	4000	1.7	–do–
20	Hf^{178}	$\frac{1}{2}$	71.1	75	1.0	–do–
21	Ta^{181}	4	13.7	21.3	1.5	Wood (1956)
22	W^{182}	$\frac{1}{2}$	9.1	19	2.1	AECU–2040 (1955)
23	Re^{185}	3	74.5	100	1.3	–do–
24	W^{186}	$\frac{1}{2}$	45.4	34	0.7	–do–
25	Re^{187}	3	39.4	63	1.6	Segre (1953) AECU–2040 (1955)
26	Ir^{193}	$g_n = 0.4 \times 10^{-3}$ev	140.9	130	0.9	Segre (1953)
27	Au^{197}	2	89.5	98	1.1	AECU–2040 (1955)

TABLE II

S.N.	Isotope	J value of compound nucleus	σ_0 in barns: calculated	σ_0 in barns: experi-mental	Ratio R	References
1	I^{127}	3	0.19+0.89 +1.10=2.18	67	30	AECU–2040 (1955)
2	Tb^{159}	2	4.9+5.1+ 0.2=10.2	44	4.3	–do–
3	Hf^{177}		214+83+5 =302	380	1.2	Igo *et al*, (1956) Segre (1953) AECU–2040 (1955)
4	Co^{59}	4	16.4	37	2.2	AECU–2040 (1955) Segre (1953)
5	Ni^{62}	$\frac{1}{2}$	1.33	15	11.2	AECU–2040 (1955)
6	Mo^{97}	3	0.3	2.1	7.0	–do–
7	Ag^{107}	1	2.6	30	11.4	Wood (1956) AECU–2040 (1955)
8	Sn^{112}	$\frac{1}{2}$	0.42	1.3	30	AECU–2040 (1955)
9	In^{113}	5	4.3	58	13.6	–do
10	Sn^{120}	$\frac{1}{2}$	0.005	0.14	26.4	–do–
11	Eu^{153}	3	1233	420	0.34	Segre (1953) AECU–2040 (1955)
12	Ho^{165}	4	21.8	64	2.9	AECU–2040 (1955)
13	Yb^{168}	$\frac{1}{2}$	3768	11000	2.9	–do–
14	Hf^{174}	$\frac{1}{2}$	2.35	1500	638	–do–
15	Hf^{179}	1	10	65	6.5	–do–
16	Hf^{180}	$\frac{1}{2}$	0.25	13	52	–do–
17	W^{183}	1	2.3	11	4.7	–do–
18	Ir^{191}	$g\Gamma_n=0.2 \times 10^{-3}$ ev	267	960	3.5	Segre (1953)
19	Hg^{199}	1	8.8	2500	284	AECU–2040 (1955)

ting σ_0 (theoretical) for Co^{59}, Γ_γ is taken to be 0.3ev as given by Segre (1953). This value of Γ_γ could be in error. In the case of Mn^{55} also Γ_γ is 0.2ev according to Segre (1953), but from the recent measurements made by Bollinger and Dahlberg (1955), $\Gamma_\gamma = 0.6$ev. As CO^{59} and Mn^{55} are very near to each other in atomic weights, and Γ_γ changes only slowly with atomic weight as pointed out by Levin and Hughes (1955), Γ_γ for Co^{59} may be taken to be $\simeq 0.6$ev. This gives the ratio R nearly equal to 1. As all the resonances in Ho^{165} and Hf^{179} are claimed to be known by Harvey *et al.* (1955), the discrepancies between the experimental and theoretical value of σ_0 cannot be accounted for by the known positive energy resonances. These again may be the cases where the negative energy resonances play some part. The rest of the cases involve so many uncertainties in the various measurements that it is very difficult to assign any particular reason for the discrepancies. In the case of isotopes of Sn and Hf, the possibility of some of the unresolved resonances is quite strong. In the case of rare earths small impurities can make great contributions in the cross-sections which could be the cause of error in some cases. Figure 1. gives the value of the ratio R for various atomic weights. The cases of discrepancy are self-evident.

ACKNOWLEDGMENTS

The authors wish to express their sincere thanks to Prof. P. S. Gill for his kind interest in this work. One of the authors (M.L.S.) is thankful to the Union Education Ministry for the grant of a Senior Research Scholarship.

REFERENCES

AEC Neutron Cross-section Advisory Group, U.S. Atomic Energy Commission Document AECU-2040 (1955)

Blatt, J. M., and Weisskopf, V. F., 1952, Theoretical Nuclear Physics, pp. 470.

Bollinger, L. M. *et al.* 1955, *Phys. Rev.*, **100**, 126.

Deutsch, R. W., 1956, *Phys. Rev.*, **104**, 555.

Harvey, J. A., *et al.* 1955, *Phys. Rev.*, **99**, 10.

Igo, G., and London, H. H., 1956, *Phys. Rev.*, **101**, 726.

Levin, J. S. and Hughes, D. J., 1955, *Phys. Rev.*, **98**, 1161.

Sailor, V. L.,1956, *Phys. Rev.*, **104**, 736.

Segre, E. (Editor), 1953, Experimental Nuclear Physics, Vol. II, pp. 324.

Wood, R. E., 1956, *Phys. Rev.* **104**, 1425.